The Impact of Practitioner Decisions on LCA for Marine Energy Converters

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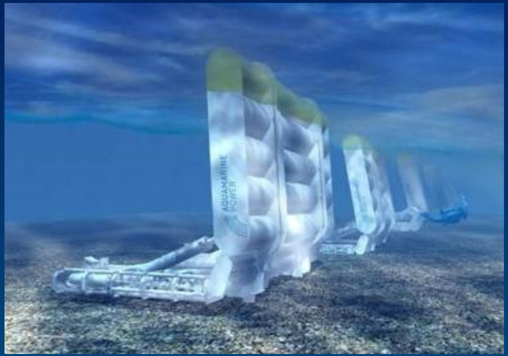
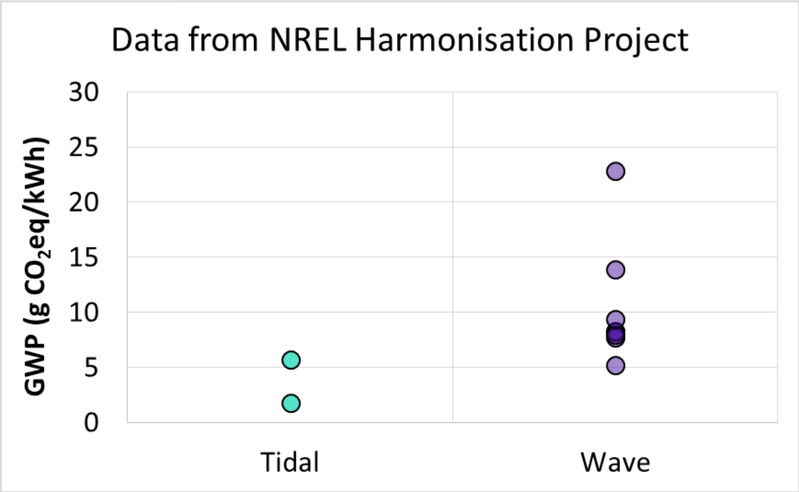
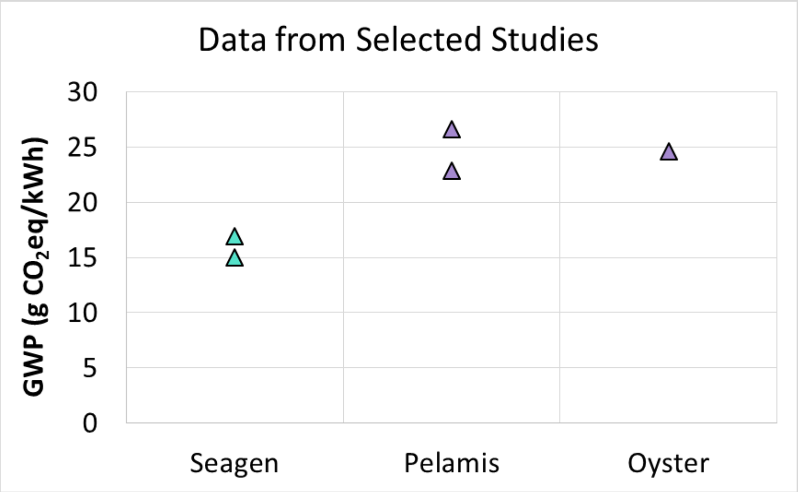


Images from www.pelamiswave.com, www.aquamarinepower.com and www.marineturbines.com

Introduction

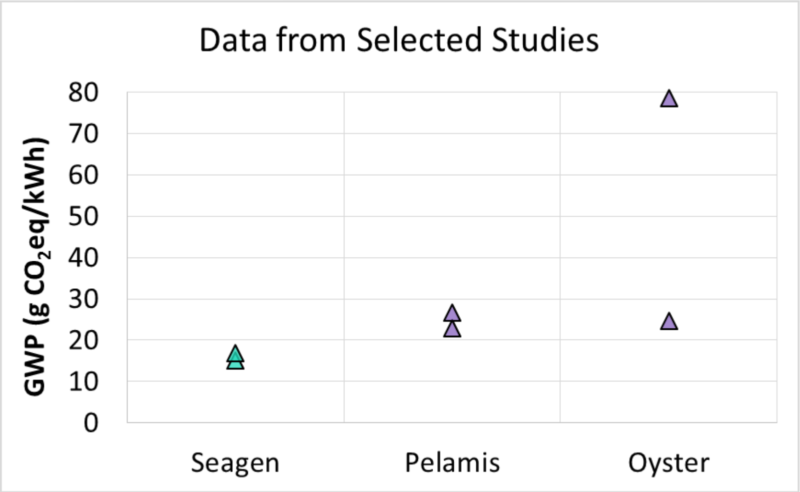


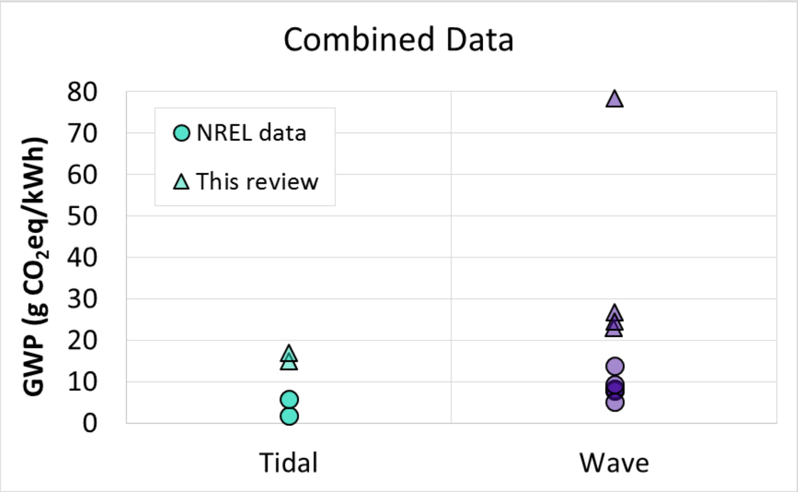


- The generic methodological framework for LCA introduces considerable scope for variation in results.
- In the marine renewable energy industry estimates of Global Warming Potential (GWP) and energy return on investment (calculated from the embodied energy) are used to inform policy and investment decisions.

NREL data taken from the LCA Harmonization Project, http://en.openei.org/apps/LCA/

Introduction





- The principal limitations of LCA have been identified in a number of reviews and meta-analyses [1-3].
- This review examines 6 studies of 3 marine energy converters, to identify and **quantify** the key sources of variation in calculated GWP and embodied energy.
- Differences in practitioner decisions are examined, and attempts are made to harmonise the results.

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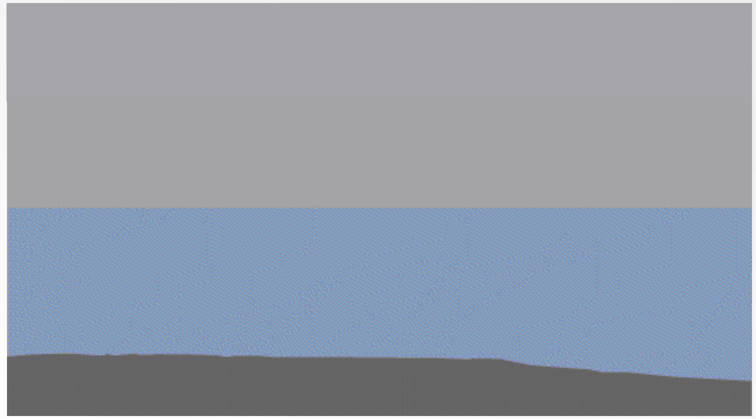
NREL data taken from the LCA Harmonization Project, http://en.openei.org/apps/LCA/

Pelamis



- Semi-submerged, snake-like offshore wave energy converter made of a series of articulating buoyant steel cylinders.
- The passage of the wave front causes the joints between the cylinders to flex, moving hydraulic rams that pump high-pressure oil through a system to drive induction generators.
- Parker et al. published a carbon and energy audit in 2007 [4].
- Thomson published a full LCA in 2014 [5].

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Pictures and graphic adapted from www.pelamiswave.com.

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Key Assumptions

	Parker et al, 2007	Thomson, 2014
Type of analysis	Partial LCI	LCA
Scope	CO_2 and energy only	EDIP 2003 and CED
Design life	20 years	20 years
Annual energy output	2.97 GWh/year	2.97 GWh/year
Tool	MS Excel	SimaPro v7.2 PhD
Secondary data source	ICE v1.5b	Ecoinvent v2.2
Cut-off criteria	Unspecified	10% for pre-fabricated components
Life cycle stages	Cradle-to-grave, no disposal impacts	Cradle-to-grave
Recycling allocation	Closed loop – some double counting	50:50 method

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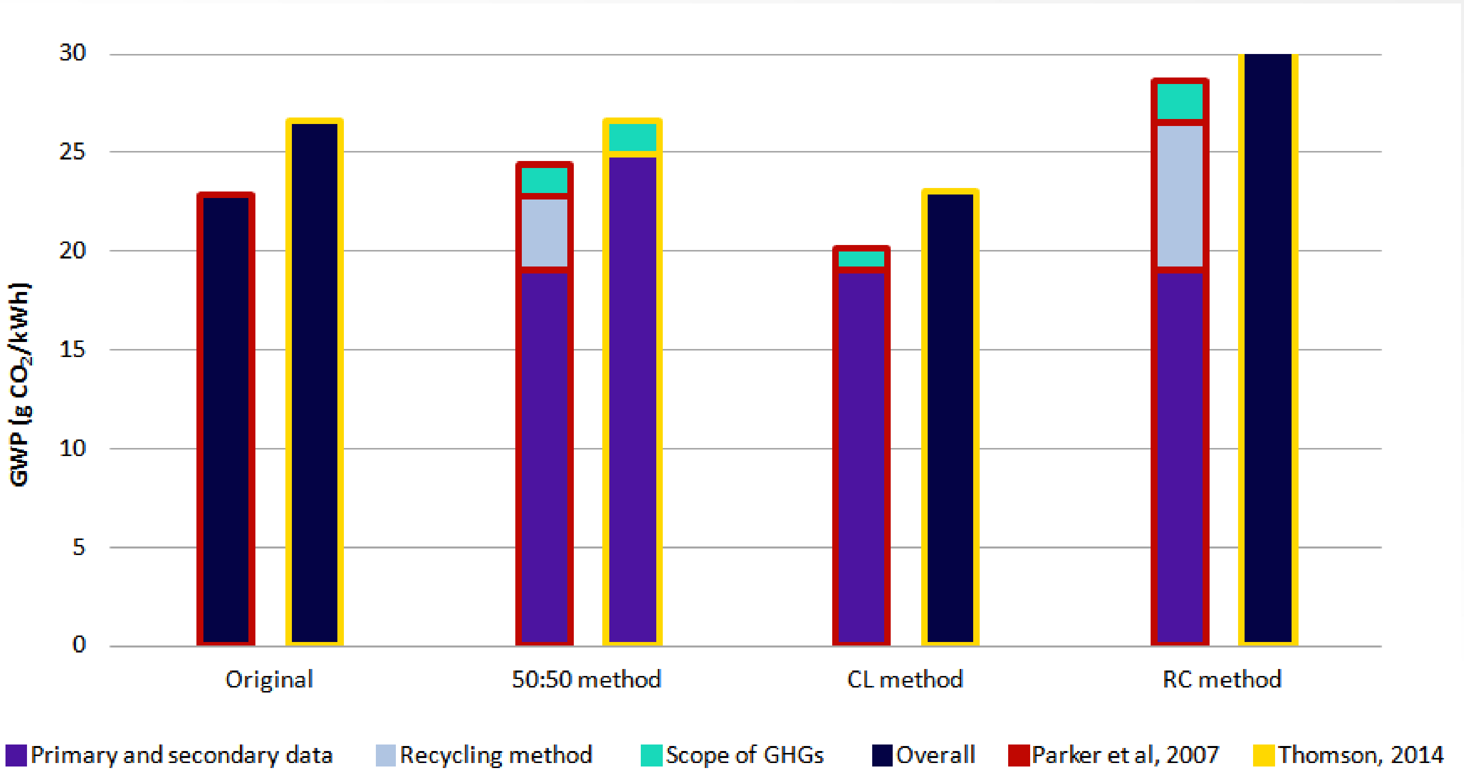
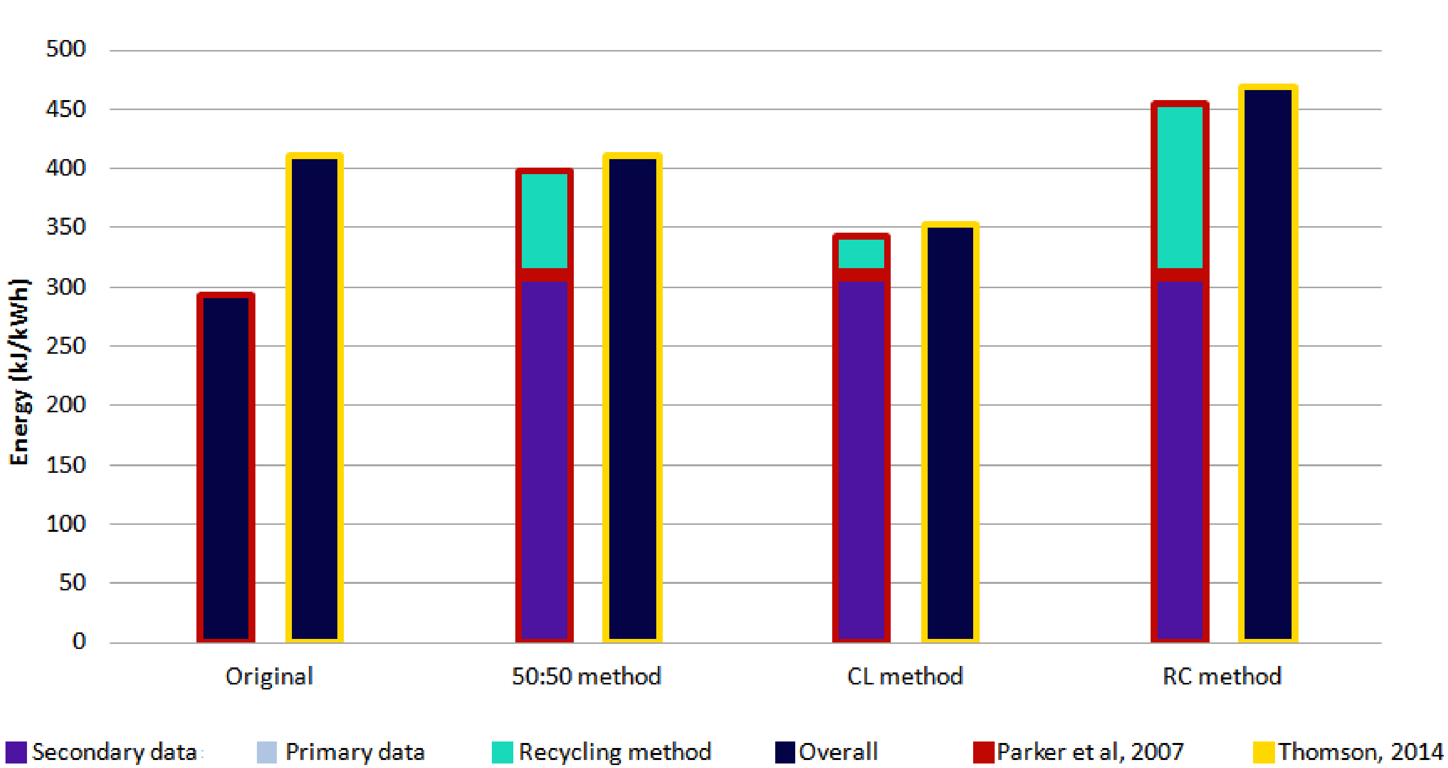
Harmonisation of GWP

g CO_2/kWh	Original	50:50 method	CL method	RC method
Parker et al, 2007	22.8	24.4	20.2	28.6
Thomson, 2014	26.6	26.6	23.0	30.3
Difference	17%	9%	14%	6%



Harmonisation of Energy

kJ/kWh	Original	50:50 method	CL method	RC method
Parker et al, 2007	293	399	343	455
Thomson, 2014	411	411	353	469
Difference	40%	3%	3%	3%



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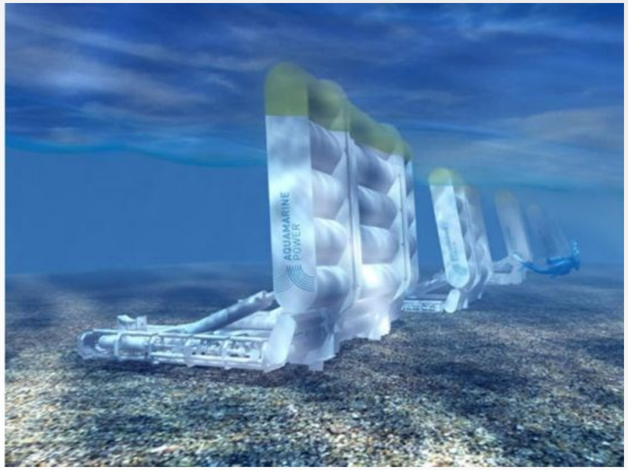
Oyster



- Buoyant hinged steel flap fixed to the sea bed.
- Wave surges induce oscillations of the flap that are resisted by hydraulic rams; these pump water through a pipe to shore, where a Pelton turbine and generator convert the energy to electricity.
- Walker and Howell published a carbon and energy audit in 2011 [6].
- Karan carried out a full LCA in 2015 [7].

Image from www.aquamarinepower.com.

Key Assumptions

	Walker and Howell, 2011	Karan, 2015
Type of analysis	Partial LCI	LCA
Scope	CO_2 and energy only	EDIP 2003 and CED
Design life	15 years	15 years
Annual energy output	1.51 GWh/year	1.51 GWh/year
Tool	Unknown	SimaPro v8 Classroom
Primary data source	Manufacturer/publications	Walker and Howell, additional publications
Secondary data source	ICE v1.5a	Ecoinvent v3
Life cycle stages	Cradle-to-grave, no disposal impacts	Cradle-to-grave
Recycling allocation	Double counting	Recycled Content

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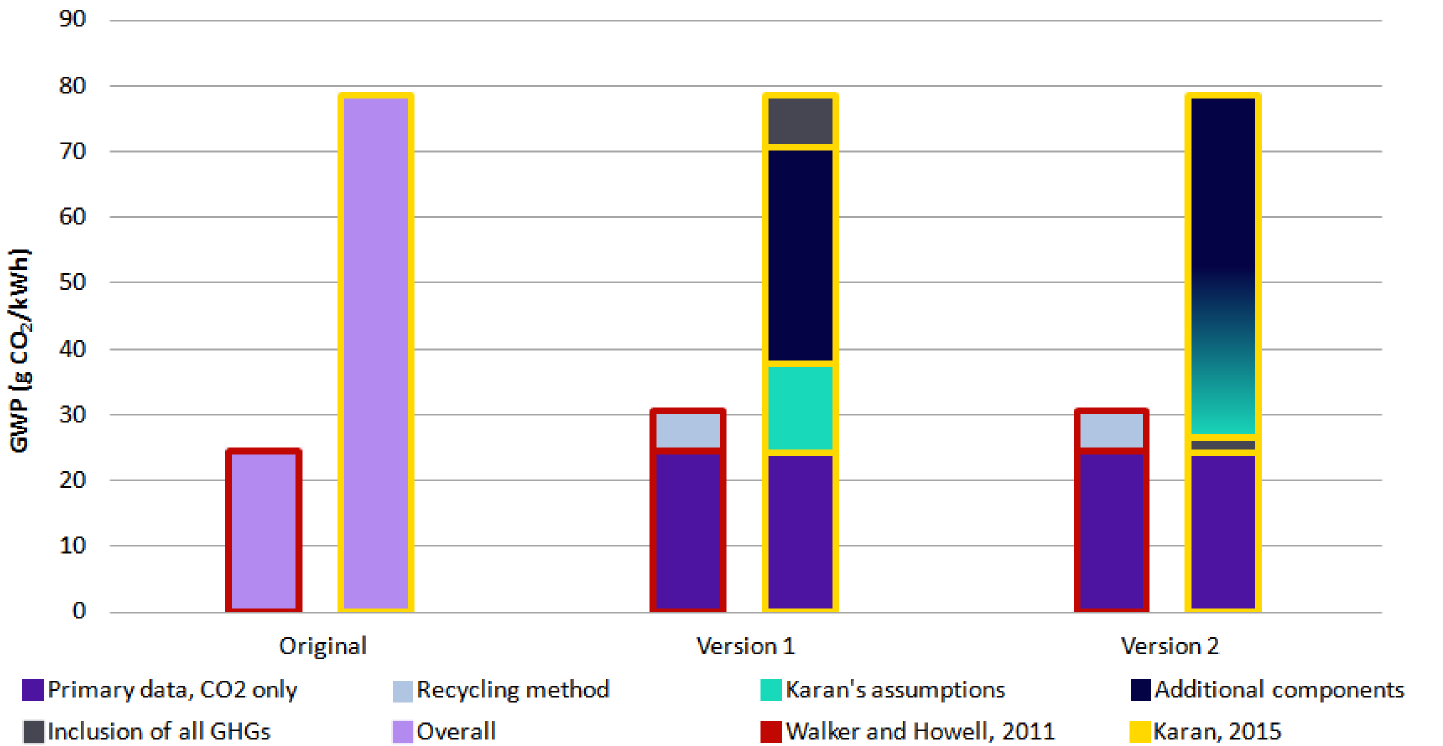
Harmonisation of GWP

g CO_2/kWh	Original	Harmonised v1 – Primary data, CO2 only	Harmonised v2 – Primary data, all GHGs
Walker and Howell, 2011	24.6	30.6	30.6
Karan, 2015	78.5	24.3	26.4
Difference	219%	21%	14%



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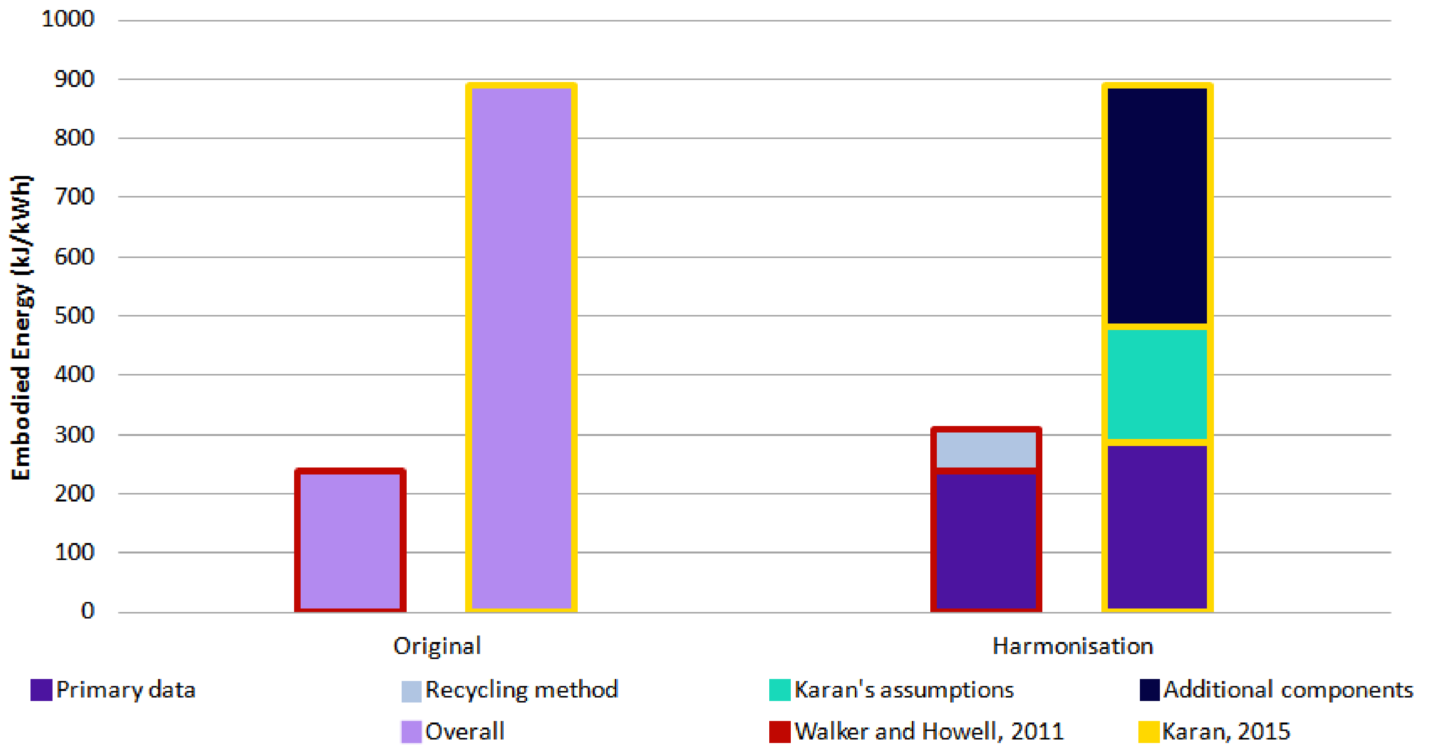
Harmonisation of Energy

kJ/kWh	Original	Harmonised – Primary data and recycling method
Walker and Howell, 2011	237	308
Karan, 2015	889	286
Difference	276%	7%



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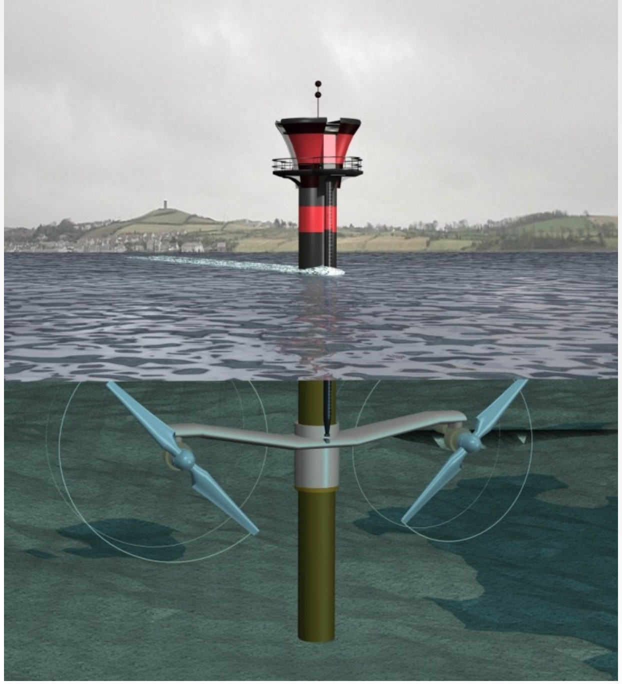
Seagen



- This extracts the energy from fast-flowing tidal currents, by means of a pair of rotors mounted on a single tower.
- Douglas et al. published a carbon and energy audit in 2008 [8].
- Miliara carried out a full LCA in 2013 [9].

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Image from www.marineturbines.com

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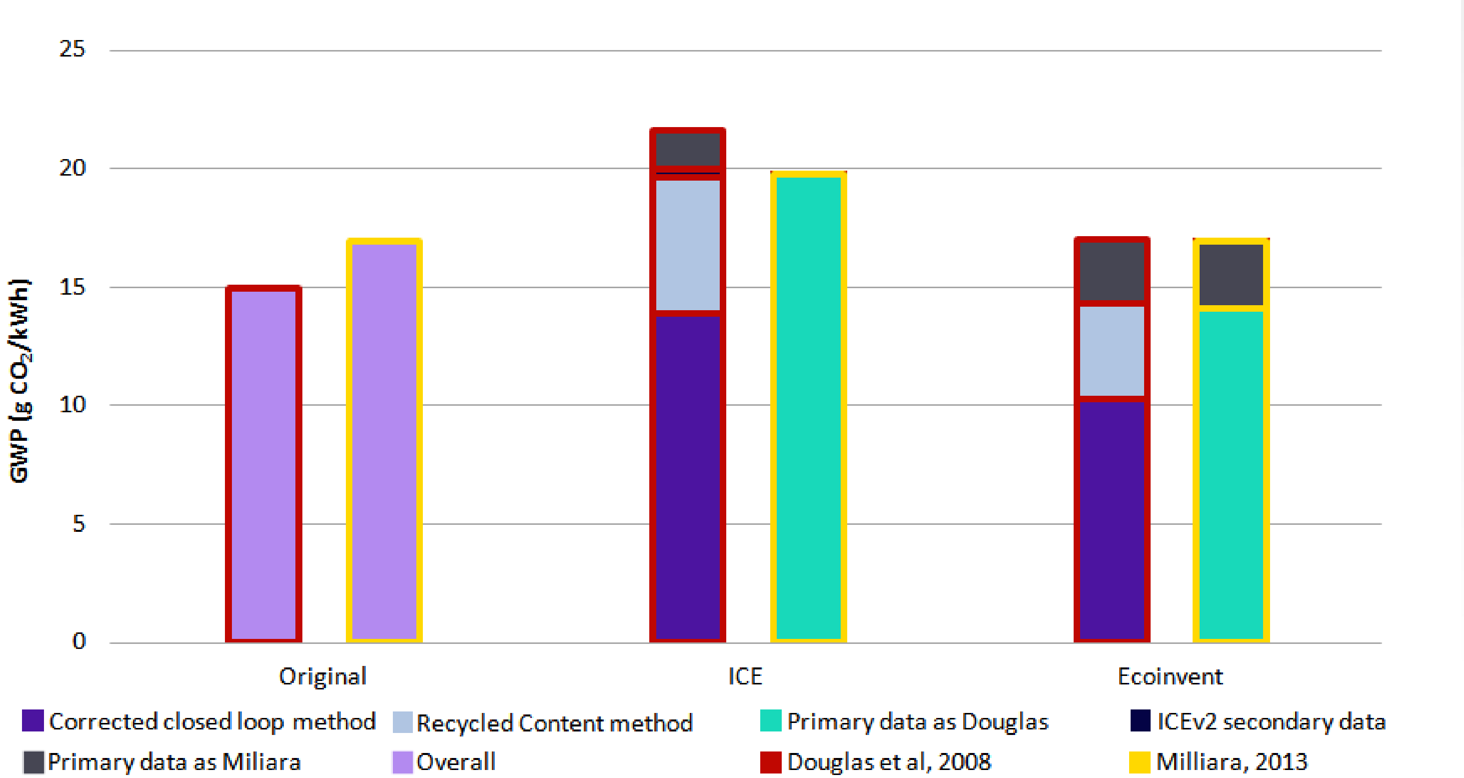
Key Assumptions

	Douglas et al., 2008	Miliara, 2013
Type of analysis	Partial LCI	LCA
Scope	CO_2 and energy only	EDIP 2003 and CED
Design life	20 years	20 years
Annual energy output	4.736 GWh/year	4.736 GWh/year
Tool	MS Excel	MS Excel
Primary data source	Manufacturer and publications	Mostly Douglas et al, 2008
Secondary data source	ICE v1.5a	Ecoinvent v2.2 or ICE v2
Life cycle stages	Cradle-to-grave, no disposal impacts	Cradle-to-grave, no disposal impacts
Recycling allocation	Closed loop – some double counting	Recycled Content

Harmonisation of GWP

g CO_2/kWh	Original	ICE v2	Ecoinvent v2.2
Douglas et al, 2008	15.0	21.6	17.0
Miliara, 2013	16.9	19.3	16.9
Difference	13%	11%	0.4%



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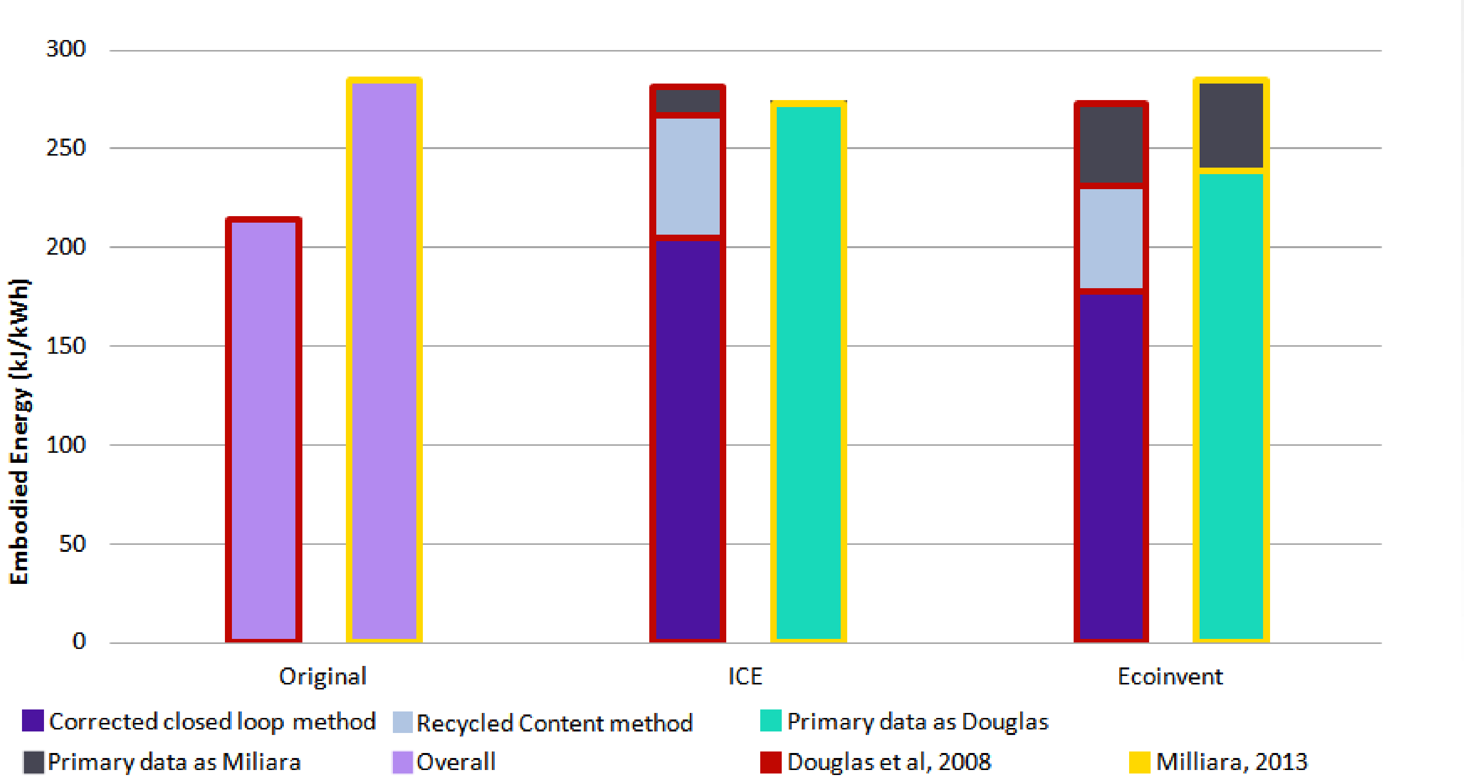
Harmonisation of Energy

kJ/kWh	Original	ICE v2	Ecoinvent v2.2
Douglas et al, 2008	214	275	273
Miliara, 2013	284	266	285
Difference	33%	3%	4%



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Key Findings

- Full harmonisation reduced discrepancies significantly.
- Once variations in primary data had been harmonised, it was found that secondary data source and the recycling allocation method were the two key sources of variation.
- Average change due to key assumptions:
  - Recycling allocation method: 34%
  - Inclusion of all GHGs (Oyster and Pelamis only): 11%
  - Secondary data source (ICEv2 and Ecoinvent – Seagen only): 33%

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PolyWEC polymeric wave energy converter

SEVENTH FRAMEWORK PROGRAMME

EPSRC Engineering and Physical Sciences Research Council

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